2

Modern Communication Systems

2.1 INTRODUCTION

Wireless communication networks have become more popular than expected at the time of 1960s and 1970s when the cellular concept was first developed. According to ITU's latest status, there are 76.2 mobile subscriptions for each 100 people which is 4.4 times the number of fixed telephone lines. On World Statistics Day, October 20, 2010. The International Telecommunication Union (ITU), the UN Agency for ICT, announced its eagerly awaited mobile estimates for 2010. By the end of the year there will be 5.3 billion mobile subscriptions. That is equivalent to 76 per cent of the world population and is a huge increase from 4.6 billion mobile subcriptions at the end of 2009. Nearly a billion of these are 3G subcriptions, and potentially mobile Web users. The mobile telephony is becoming more and more ubiquitous. In developed countries, the growth is slowing down with average penetration rates above 100 per cent. But in developing countries, growth is still strong and therefore more and more people will be connected to telephones who never had access to a telephone at all in the past, thus mobile revolution is continuing. The telecom story continues to grow in India also. As the number of users are increasing so there is need to invent new technologies to fulfil the requirement of users.

This chapter highlights the key developments in wireless communication about the first generation, second generation, third generation, fourth generation and about wireless networks, wireless local loop, wireless local area networks, Bluetooth and personal area networks.

2.2 FIRST GENERATION (1G)

1G is short for first generation wireless technology cellphones. These are analog cellphones standards and were introduced in 1980. 1G uses digital signalling

2.3.6 Advantages

(i) *Enhance Privacy:* As digital cellular calls are much harder to eavesdrop.
(ii) Improve sound quality by reducing dynamic and lowering noise floor.
(iii) Requires less battery power. So phones last much longer.
(iv) Lower power emission.

2.3.7 Disadvantages

(i) The range of sound conveyed is reduced.
(ii) Weaker digital signal may not be sufficient to reach a cell tower.
(iii) A digital signal has jagged steppy curve which under slightly worst condition will experience dropouts.
(iv) Most susceptible to static and noise.

2.4 GENERATION (2.5G)

This generation is used to describe 2G system that has implemented a packet switch domain to circuit switch domain. It not only provides faster services but also provides compatibility with the older handsets. GPRS is often described as 2.5G. It uses TDMA. 2.5G provides benefits of 3G, i.e., it is packet switched and can use some of the existing infrastructures in GSM and CDMA networks.

2.4.1 GPRS

It stands for General Packet Radio Services. It is packet oriented mobile data service available to users of 2G communication cellular systems–GSM as well as in 3G system. In 2G systems it provides data rate from 56-114 kbps. It uses TDMA services. The multiple access method used in GSM with GPRS uses FDD and TDMA. A user is assigned to one pair uplink and downlink frequency channel. This is combined with packet mode communication which makes it possible for several users to share the same frequency channel. The uplink using scheme is very similar to slotted ALOHA and the downline uses first come first serve packet scheduling.

This connection is established by reference to its Access Point Name (APN). It defines services such as WAP, SSUS and MMS.

GPRS supported Internet protocol and point-to-point protocol and X. 25 connections.

2.4.2 GPRS Characteristic

(i) It uses packet switched resource allocation. Resources are allocated only when data is to be sent/received.

(ii) Flexible channel allocation
  (a) One to eight time slot
  (b) Available resources shared by active users
  (c) Up and downlink channels reserved separately.
  (d) GPRS and circuit switched GSM services can use same time slot alternatively.
(iii) Traffic characteristic suitable for GPRS
  (a) Intermittent, bursty data transmission
  (b) Frequent transmission of small volume of data.

2.4.3 Applications

(i) SMS delivery
(ii) GPRS specific protocol based
  (a) Point-to-point application.
  (b) Point-to-multipoint application.
(iii) Standard data network protocol based
  (a) IP based application
  (b) X.25 based application
  (c) TCP/IP based application.

2.5 THIRD GENERATION (3G)

3G is third generation of tele standards and technology for mobile networking. It is based on ITU family of standards under IMT-2000. 3G networks provide wider range of more advanced services while achieving greater network capability through improved spectral efficiency. Services include wide area wireless voice telephony video calls at broadband wireless data. It offers high data transmission capability of 14.4 Mbps for downlink and 5.8 Mbps for the uplink. Wi-Fi and WLAN networks are short range high bandwidth networks as compared to 3G networks. 3G networks are wide area cellular telephone networks that evolved to incorporate high-speed internet access and video telephony.

W-CDMA is a 3G cellular network. It is high-speed transmission protocol.

2.5.1 Introduction to 3G and 4G

Cellular networks are used for handling mobile phones, traffic and many more other applications. With the passage of time there have been developments of more complex applications like email, audio and video streaming and game playing over the wireless system. To handle these applications, cellular networks are also upgraded time to time. Different types of cellular networks that came into existence with time are as shown below:

Cellular Networks Generation		Cellular Networks Standards
1G	analog	AMPS, TACS, NAMPS
2G	digital	GSM, TDMA, CDMA
3G	digital	W-CDMA, CDMA-2000
4G	digital	LTE, Wimax

3G cellular technology is defined as the provision of wireless broadband data and information services right to a person's mobile unit. Compared to the previous technologies, 3G promises speeds ranging from 144 kbps, which is 3 times faster as compared to the traditional 56 K dial-up modem connection up to 2.4 Mbps, which is very near to cable-modem speed. The networks of 3G allows you to browse quickly through web pages, watch on-demand video programs, download and play music, videos and 3D games, watch streaming videos and music videos and videoconference with others located on the other side of the planet.

3G comprises several cellular access technologies.

2.5.2 Technology Used

- CDMA 2000 – It is based on 2G Code Division Multiple Access
- WCDMA (UMTS) – Wideband Code Division Multiple Access
- TD-SCDMA – Time-division Synchronous Code-division Multiple Access

3G networks have potential of transfer speeds of up to 3 Mbps (about 15 seconds to download a 3-minute MP3 song). For comparison, the fastest 2G phones can achieve up to 144 kbps (about 8 minutes to download a 3-minute song). 3G's high data rates are ideal for downloading information from the Internet and sending and receiving large, multimedia files. 3G phones are like mini-laptops and can accommodate broadband applications like videoconferencing, receiving streaming video from the Web, sending and receiving faxes and instantly downloading e-mail messages with attachments.

2.5.3 Features of W-CDMA

It supports 21 Mbps data transfer rate. UMTS over W-CDMA uses pair of 5 MHz standards. UMTS network provides applications such as videocalling and often utilized for Internet access.

2.5.4 3G Wireless Networks

3G CDMA 2000: This standard allows the high data rate Internet access up to 307 kbps in packet form. It gives double voice capacity as compared to 2G CDMA.

2.5.5 Applications

The bandwidth and location information available to 3G devices gives rise to applications not previously available to mobile phone users. Some of the applications are:

- **Mobile TV** – A service provider redirects a TV channel directly to the subscriber's phone where it can be watched.
- **Video on demand** – A service provider sends a movie to the subscriber's phone.
- **Videoconferencing** – Subscribers can see as well as talk to each other.
- **Tele-medicine** – A medical provider monitors or provides advice to the potentially isolated subscriber.
- **Location-based services** – A service provider sends localized weather or traffic conditions to the phone, or the phone allows the subscriber to find nearby businesses or friends.

2.5.6 Advantages of 3G Technology

High Bandwidth

- High bandwidth is the measure of transmission capacity which is one of the selling points of 3G. This allows you quick and easy access to all of your favourite online multimedia and Internet tools, just like you were at home on a computer. You can pay bills, book dinner reservations, update social networking pages and check emails, all on-the-go. While the maximum bandwidth for a stationary 3G device—according to Silicon Press—is 2.05 megabytes (MB), when you are moving slowly (such as walking), this drops to 384 kilobytes (KB), When you and your device are moving at high speeds (such as in car), the maximum bandwidth drops to 128 KB. However, Silicon Press notes that this is still 10 times faster than the maximum bandwidth of moving 2G devices.

Always-Online Devices

- Another advantages of 3G technology is that it can utilize packet-based Internet protocol connectivity. This means your mobile device will always be online and ready for Internet access. However, you will not actually pay for the connection until you start sending or receiving data packets, such as sending an email or looking at a web page. Some 3G devices are also designed to automatically pick up the closest, free-to-access Wi-Fi signals, in which case, you won't have to pay anything for Internet.

Associated Costs

- To support 3G technology, updates need to be made to the current cellular infrastructure. According to 3G Internet, this means installing new

3G equipment at every current cellular base station and acquiring new frequencies for 3G transmissions. Both of these undertakings are expensive and could take a long time to complete fully. In addition, in order to utilize all of the new features 3G technology, customers must have 3G-compatilible handsets, which are generally more expensive than their 2G counterparts.

Power Requirements

- In addition to being more expensive, 3G handsets also require more power than most 2G models. According to Silicon Press, this extra power requirement can translate to larger batteries, shortage usage periods between recharging and more bulky handsets overall.

2.5.7 Disadvantages of 3G Technology

- Penetration of Internet is still below average in rural India. Understanding the tech-savvy specifications of 3G technology will definitely be problem.
- This technology is not compatible with all mobile phones. The user has to buy a new mobile phone that can support 3G technology.
- Till its launch, there are only two service providers offering 3G technology service. Lack of multiple options might be a disadvantage.
- Videoconferencing is not possible if one of the persons engaged in the conversation and does not have 3G compatible phone.

2.6 EVOLUTION FROM 2G TO 3G

It can be divided into the following phases:

(i) *From 2G to 2.5G (GPRS):* Evolution of 3G occurred with introduction of GPRS. It provides data rate from 56 kbps-114 kbps.

(ii) *From 2.5G to 2.75G:* GPRS networks evolved to EDGE networks with introduction of 8 PSK encoding EDGE or enhanced GPRS is backward compatible digital phone that allows improved data transmission rate. It is used for packet switch application such as the Internet.

(ii) *From 2.75G to 3G:* From EDGE network evolved to introduction of UMTS network. This was known as 3G.

2.6.1 Advantages

(i) It provides high security by allowing UE to authenticate the network from attacking. The user can be sure the network is the intended one and not an impersonator.

(ii) It provides higher transmission rate with a minimum speed of 2 Mbps and maximum of 14 Mbps for stationary users and 348 kbps for moving users. It also provides global roaming.

2.6.2 Disadvantages

(i) High prices of 3G phone
(ii) Numerous differences in leicusug term.
(iii) Lack of coverage
(iv) Current lack of user need of 3G voice and data services.
(v) Expensive input fee for 3G service licence.

2.7 FOURTH GENERATION (4G)

4G is an abbreviation for fourth generation. A 4G system will be able to provide voice, data and multimedia to the users on an 'Anytime, Anywhere' basis and at higher data rates than previous generations.

4G is a total replacement of 3G networks and handsets. 4G will be a fully IP-based integrated system which will be capable of providing between 100 Mbps and 1 Gbps speeds both indoors and outdoors, with premium quality and high security.

About 4G Technology

INTRODUCTION

The approaching 4G (fourth generation) mobile communication systems are projected to solve still-remaining problems of 3G (third generation) systems and to provide a wide variety of new services, from high-quality voice to high-definition video to high data rate wireless channels. The term 4G is used broadly to include several types of broadband wireless access communication systems, not only cellular telephone systems. One of the terms used to describe 4G is MAGIC—**M**obile multimedia, **A**nything anywhere, **G**lobal mobility support, **I**ntegrated wireless solution, and **C**ustomized personal service. As a promise for the future, 4G systems, that is, cellular broadband wireless access systems, have been attracting much interest in the mobile communication arena. The 4G systems not only will support the next generation of mobile service, but also will support the fixed wireless networks. This new generation of wireless is intended to complement and replace the 3G systems, perphaps in 5 to 10 years. Accessing information anywhere, anytime, with a seamless connection to a wide range of information and services, and receiving a large volume of information, data, pictures, video, and so on, are the keys of the 4G infrastructures. The future 4G infrastructures will consist of a set of various networks using IP (Internet protocol) as a common protocol so that users are in control because they will be able to choose every application and environment.

Based on the developing trends of mobile communication, 4G will have broader bandwidth, higher data rate, and smoother and quicker handoff and will focus on ensuring seamless service across a multitude of wireless systems and networks.

The key concept is integrating the 4G capabilities with all of the existing mobile technologies through advanced technologies.

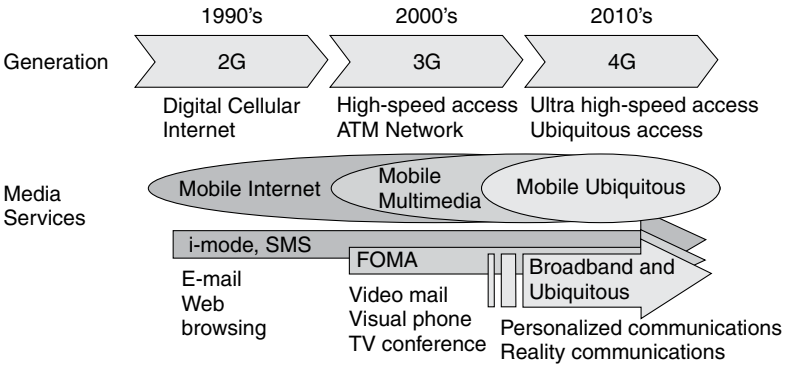

Fig. 2.1(a) Path from 2G to 4G.

Application adaptability and being highly dynamic are the main features of 4G service of interest to users.

These features mean services can be delivered and are available to the personal preference of different users and support the user's is traffic, air interfaces, radio environment, and quality of service. Connection with the network applications can be transferred into various forms and levels correctly and efficiently. The dominant methods of access to this pool of information will be the mobile telephone, PDA, and laptop to seamlessly access the voice communication, high-speed information services, and entertainment broadcast services. Figure 2.1(b) illustrates elements and techniques to support the adaptability of the 4G domain. The fourth generation will encompass all systems from various networks, public to private; operator-driven broadband networks to personal areas; and ad hoc networks. The 4G systems will interoperate with 2G and 3G systems, as well as with digital (broadband) broadcasting systems. In addition, 4G systems will be fully IP-based wireless Internet.

This all-encompassing integrated perspective shows the broad range of systems that the fourth generation intends to integrate, from satellite broadband to high altitude platform to cellular and 3G systems to WLL (wireless local loop) and FWA (fixed wireless access) to WLAN (wireless local area network) and PAN (personal area network), all with IP as the integrating mechanism.

2.7.1 Requirements of 4G & Objectives

4G is being developed to accommodate the applications like MMS, video chat, mobile TV, HDTV content, digital video broadcasting, etc. 4G working group has defined the following objectives:

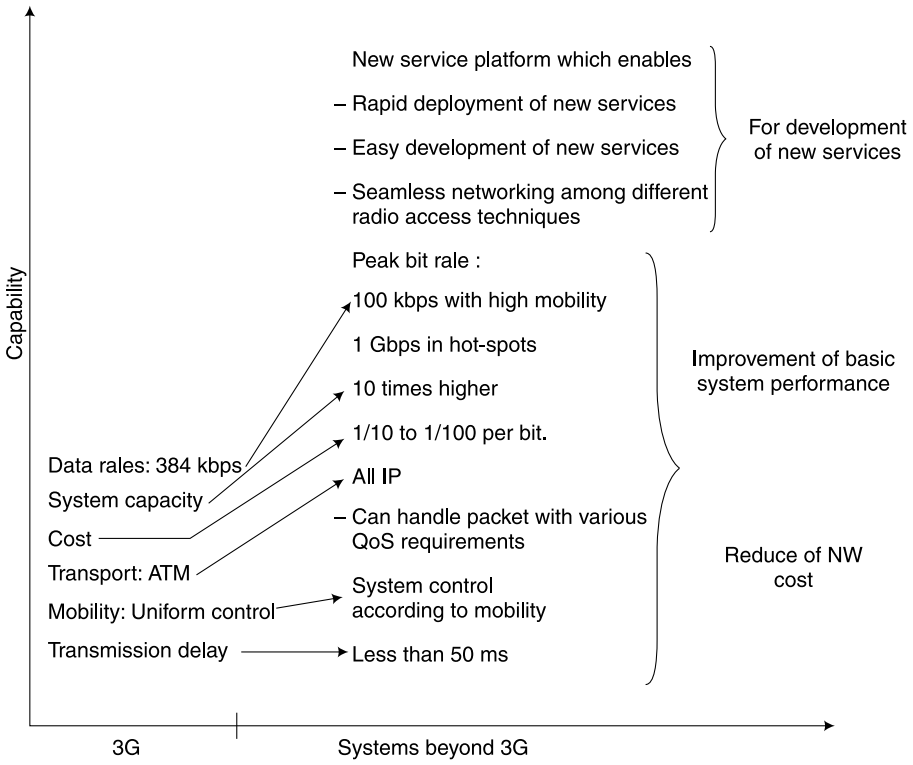

Fig. 2.1(b)

- A spectrally efficient system (in bit/s/Hz)
- High network capacity: more simultaneous users per cell.
- High data rates of 100 Mbps while the client physically moves at high-speed relative to station and 1 Gbps while client and station are in relatively fixed position.
- Smooth hand off across heterogeneous networks.
- Seamless connectivity and global roaming cross multiple networks.

1. Broadband Wireless Access

The traffic carried by mobile communication systems was mainly for voice communications. The second generation (2G) system, the Personal Digital Cellular (PDC) system, introduced the i-mode services, which enabled the Internet access, electronic commerce and e-mail from mobile terminals, and mainly used for the text-based data communications. The IMT-2000 system offers high bit rate transmission service from 64 kbit/s to 385 kbit/s, and it is expected that the proportion of the amount of data traffic to the voice traffic would continue to increase. Moreover, the rising popularity of broadband services such as Asymmetric Digital Subscriber Line (ADSL) and optical fibre access systems and office or home

LANs is likely to lead to a demand for comparable services in the mobile communication environment.

2. Low Cost

To make broadband services available to the user to exchange various kinds of information, it is necessary to lower charges dramatically in order to keep the cost at or below the cost of existing service. The IMT-2000 system aimed at lower bit cost and economical charge rates, however, for the 4G system, a broadband channel and an even lower bit cost are both required.

3. Wide Area Coverage

One feature of mobile communication is that it is available for use anytime and anywhere. That advantage is important to future mobile communication as well. In particular, it is important to maintain the service area in which the terminals of the new system can be used during the transition from the existing system to a new system. It can be assumed that terminals that have relatively large display screens, such as Personal Digital Assistant (PDAs) or personal computers are used indoors rather than outdoors. Accordingly, better coverage of indoor service areas is needed.

4. Capable for Wide Variety of Services

Mobile communication is for various types of users. In the future, we expect to make the advanced system performance and functionality to introduce a variety of services not only the ordinary telephone service but to transfer information about the five sensual modes. Those services must be made easier for anyone to use.

2.7.2 Technologies

(a) *OFDM:* Orthogonal Frequency Division Multiplexing is as FDM scheme utilized as a digital multicarrier modulation method. A large number of closely spaced orthogonal subcarriers are used to carry data. The data is divided into several parallel data streams or channels one for each sub-carrier. Each sub-carrier is modulated with a conventional modulation scheme (such as QAM, PSK, etc.).

(b) *MIMO:* Multiple Input Multiple Output is the use of multiple antennas at transmitter and receiver to improve communication performance. It offers significant increase in data throughput and link range without additional bandwidth or transmiting power.

(c) *Turbo Code:* These are a class of high performance error correction codes developed in 1993 which are finding use in deep space satellite communication and in applications where maximal information transfer takes place over a limited bandwidth communication link in the presence of data corrupting noise.

- Modulation, spatial processing including multi-antenna and multi-user MIMO.

2.7.3 Components

The infrastructure and terminals of 4G will have almost all the standards from 2G to 4G. The infrastructure for 4G will be packet based only. Technologies considered to be early 4G include Flash-OFDM. 802.16 c version of WiMax.

- ***Access scheme:*** Recently, access schemes like OFDMA, Single carrier FDMA, multicarrier CDMA are used for 4G system. WiMax is using OFDMA in downlink and in uplink. These access schemes offer same efficiencies as older technologies like CDMA.
- ***IPv6:*** As 4G will be based on packet switching only so it will require low latency data transmission. By the time that 4G is deployed, the process of IPv4 address execution is expected to be in its final stage, so IPv6 support is essential in order to support large number of wireless devices. IPv6 is a method of sharing a limited number of addresses among large group of devices.
- ***Advanced Antenna Systems:*** Multiple antenna technologies are emerging to achieve the goal of 4G systems such as high rate, high reliability and long range communications.

2.7.4 Applications

At the present rates of 15-30 Mbps, 4G is capable of providing users with streaming HDTV.

At rates of 100 Mbps, the contents of DVD-5 (for example, a movie) can be downloaded within 5 minutes for offline access.

2.7.5 ITU Requirements

As defined by ITU-R An IMT-Advanced cellular system must fulfil the following requirements:

- Based on an all-IP packet switched network.
- Peak data rates of up to approximately 100 Mbit/s for high mobility such as mobile access and up to approximately 1 Gbit/s for low mobility such as nomadic/local wireless access, according to the ITU requirements.
- Dynamically share and utilize the network resources to support more simultaneous users per cell.
- Scalable channel bandwidth, between 5 and 20 MHz, optionally up to 40 MHz.
- Peak link spectral efficiency of 15 bit/s/Hz in the downlink, and 6.75 bit/s/Hz in the uplink (meaning that 1 Gbit/s in the downlink should be

possible over less than 67 MHz bandwidth) and similar system spectral efficiency.

- Smooth handovers across heterogeneous networks.
- Ability to offer high quality of service for next generation multimedia support.

In September 2009, the technology proposals were submitted to the International Telecommunication Union (ITU) as 4G candidates.

IEEE Standards

The IEEE is working on wireless standards that are optimized for a particular domain: 802.15 for the wireless personal area network (WPAN), 802.11 for the wireless local area network (WLAN), and 802.16 for the wireless metropolitan-area network (WMAN). Implementation of these technologies, including the following, address the 4G goal of very high data rates:

- 802.15.3a (ultra wideband [UWB]) with a short-range throughput of 480 Mbps
- 802.11n (multiple input, multiple output [MIMO] WLAN) with a medium-range throughput of 100 Mbps
- 802.16-2004 (WiMAX) with a long-range throughput of 75 Mbps

To achieve the vision of 4G, mobility has to be added to these systems. The following standards address the mobility issue:

- 802.16e—This is an enhancement to the WiMAX standard.
- 802.20—This will support data rates up to 4 Mbps with frequencies up to 3.5 GHz. This standard will allow cellphones to operate from vehicles travelling at up to 250 km per hour and could be based on orthogonal frequency division multiplexing (OFDM), code division multiple access (CDMA), and multi-antenna techniques.

2.7.6 Comparison of Mobile Access Methods

Standard	*Family*	*Primary Use*	*Radio Tech*	*Downlink (Mbit/s)*	*Uplink (Mbit/s)*	*Notes*
LTE	UMTS/4GSM	General 4G/	OFDMA/MIMO/ SCFDMA	100(in 20 MHz Bandwidth)	50(in 20 MHz Bandwidth)	LTE-Advanced update expected to offer peak rates up to 1 Gbit/s fixed speeds and 100 Mb/s to mobile users. WiMAX update IEEE

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WiMAX	802.16	Mobile Internet	MIMO-SOFDMA	128 in 20 MHz bandwidth	56(in 20 MHz bandwidth)	802.16 m expected to offer peak rates of at least 1 Gbit/s fixed speeds and 100 Mbit/s to mobile users.
Flash-OFDM	Flash-OFDM	Mobile Internet mobility up to 200 mph (350 km/h)	Flash-OFDM	5.3 10.6 15.9	1.8 3.6 5.4	Mobile range 30 km (18 miles) extended range 55 km (34 miles)
HIPERMAN	HIPERMAN	Mobile Internet	OFDM	56.9		
Wi-Fi	802.11 (11n)	Mobile Internet	OFDM/MIMO	300 (using 4 × 4 configuration 20 MHz bandwidth) or 600 (using 4 × 4 configuration in 40 MHz bandwidth)		Antenna, RF front end enhancements and minor protocol timer tweaks have helped deploy long range P2P networks compromising on radial coverage, throughput and/or spectra efficiency (310 km & 382 km)

2.7.7 Advantages and Disadvantages

Advantages

- Higher bandwidth
- Better response time. 10 times better than 3G
- Works at 2.6 GHz frequency which means better coverage even though it uses the same tower where the reciever and transmitter for 3G is.
- Less time to build 4G because it uses the same tower and fibre cables as 3Gs—they only have to upgrade the towers with 4G components.
- Provides higher flexibility as compared to already existing technologies.

Disadvantages

- New technology which makes it more expensive than 3G
- Better usage is more.

- Needs complicated hardware.
- Not compatitible with already existing 2G and 2.5 G handsets.

2.7.8 WiMAX

WiMAX stands for Worldwide Interoperability for Microwave Access. WiMAX technology enables ubiquitous delivery of wireless broadband service for fixed and/or mobile users. The air interface of WiMAX technology is based on the IEEE 802.16 standards. In particular, the current Mobile WiMAX technology is mainly based on the IEEE 802.16e amendment (IEEE, 2006a), approved by the IEEE in December 2005, which specifies the Orthogonal Frequency Division Multiple Access (OFDMA) air interface and provides support for mobility.

The selection of features to be implemented in WiMAX system and devices is presented in the moblie WiMAX System Profile Release 1.0 (WiMAX Forum, 2007) which was developed in early 2006 and is currently maintained by the WiMAX Forum

Key MAC Features

The MAC layer of mobile WiMAX (802.16e) technology includes the following features which provide for high efficiency and flexibility:

1. Connection-based Data Transmission with Classification and QoS per Connenction

The WiMAX technology provides an environment for connection-oriented services. For each service, certain classification rules are specified to define the category of traffic associated with the connection. For example, it could be Internet Protocol (IP) traffic designed for a specific IP address/port. For each connection, certain QoS parameters are defined, for example, the minimum reserved rate and maximum sustained rate. There are several types of scheduling such as real-time services that can be applied based on the application requirements. A special scheduling type is defined for the VoIP service with silence suppression and adaptive codecs.

2. Scheduled Transmissions and the Flexible Bandwidth Allocation Mechanism

Bandwidth allocation mechanism is based on real-time bandwidth requests transmitted by the terminals, per connection. Bandwidth requests may be transmitted using a contention based mechanism or they can be piggybacked with the data messages. The base station executes resources allocation based on the requests and QoS parameters of the connection.

3. MAC Overhead Reduction

WiMAX technology includes support of the general Purpose Header Suppression (PHS) and IP Header Compression (ROHC). PHS can be used for packets of virtually any format such as IPv4, IPv6 over Ethernet. It is beneficial if a considerable part of the traffic has identical headers which is typical for IP or

Ethernet destination addresses. The PHS mechanism replaces the repeated part of the header with a short context identifier, thus reducing the overhead associated with headers.

4. Mobility Support: Handover

Handover procedures include numerous means of optimization. In particular, to reduce time expense for the mobile to find the central frequency and acquire parameter of the neighbour base station, the mobile can apply a scanning process when the mobile is away from the serving base station to scan the wireless media for neighbour base stations.

Information collected during scanning such as central frequencies of the neighbour base station can be used in actual handover. In some deployment, scanning can be performed without service interruption. For this purpose, information about the central frequency and parameters of the neighbour base stations is periodically advertised by the serving base station.

To shorten the time needed for the mobile to enrol into the new cell the network is capable of transferring the context associated with the mobile from the serving base station to the target base station.

All of these means provide a potential for high optimization in terms of handover latency. Under ideal conditions the interval of service interruption may be as short as several 5 ms frames. The specific handover optimization scheme used in a particular handover depends on the information available to the mobile.

5. Power Saving: Sleep Mode

Sleep mode is the primary procedure for power saving. In sleep mode the mobile is away from the base station for certain time intervals, normally of exponentially increasing size. During these intervals the mobile remains registered at the base station but can power down certain circuits to reduce power consumption.

6. Power Saving: Idle Mode

If the mobile has no traffic for a long time it can switch to idle mode in which it is no longer registered at any particular base station. To resume traffic between the network and the mobile, a paging procedure may be used by the network.

7. Security

The security sublayer provides Extensible Authentication Protocol (EAP)-based mutual authentication between the mobile and the network. It protects against unauthorized access to the transferred data by applying strong encryption of data blocks transferred over the air. To keep the encryption keys fresh, the security sublayer employs an authenticated client/server key management protocol which allows the base station to distribute keying material to mobiles. Basic security mechanisms are strengthened by adding digital-certification-based Subscriber Station (SS) device authentication to the key management protocol.

8. MAC Layer Support for the Multicast and Broadcast Service

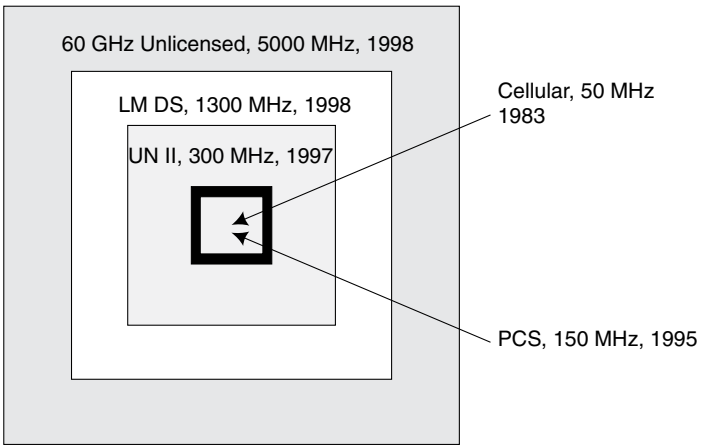
Multicast and Broadcast Services (MBSs) allows WiMAX mobile terminals to receive multicast data even they are in idle mode. The most popular application of this feature is TV broadcasting to mobile terminals.

2.8 DIGITAL CELLULAR SYSTEM PARAMETERS

Particulars	*GSM*	*IS-136*	*IS-95*
Year introduced	1990	1991	1993
Access method	TDMA	TDMA	CDMA
Base station transmission band	935-960 MHz	869-894 MHz	869-894 MHz
Mobile station transmission band	890-915 MHz	824-849 MHz	824-849 MHz
Spacing between forward and reverse channels	45 MHz	45 MHz	45 MHz
Channel bandwidth	200 kHz	30 kHz	1250 kHz
Number of duplex channels	125	825	20
Mobile unit max. power	20 W	3 W	0.2 W
Users/channel	8	3	35
Modulation	GMSK	$\frac{\pi}{4}$ DQPSK	QPSK
Carrier bit rate	270.8 kbps	48.6 kbps	9.6 kbps
Speech coder	RPE-LTP	VSEL-P	QCELP
Speech coding bit rate	13 kbps	8 kbps	8, 4, 2, 1 kbps
Frame size	4.6 ms	40 ms	20 ms
Error control coding	Convolutional $\frac{1}{2}$ rate	Convolutional $\frac{1}{2}$ rate	Convolutional $\frac{1}{2}$ rate forward, $\frac{1}{3}$ rate reverse

2.9 DIFFERENCES BETWEEN ANALOG CELLULAR AND DIGITAL CELLULAR SYSTEMS

1. ***Digital traffic channels:*** First generation systems are almost purely analog whereas second generation systems are digital. In particular, they are designed to support voice channels using FM, digital traffic is supported only by the use of modem that converts digital data into analog form. Second generation systems provide digital traffic channels.
2. ***Encryption:*** Because of user and control traffic is digitalized, it is relatively simple to encrypt all of the traffic to prevent eavesdropping whereas first generation systems send user traffic in clear, providing no security.



Comparison of spectrum allocations for various US wireless communication services

Fig. 2.3

LMDS is a brand new type of service, dependent upon millimetre wave equipment that is still expensive. Nevertheless, the vast bandwidth capabilities of LMDS for WLL applications will some day prove valuable. The free spectrum available at 60 GHz provides an enormous incentive to reduce the cost of millimetre wave electronics for consumer use.

One of the most promising applications for LMDS is in a local exchange carrier (LEC) network. As long as a LOS path exists, LMDS will allow LECs to install wireless equipment on the premises of customers for rapid broadband connectivity without having to lease or install its own cables to the customers.

Finding a line-of-sight path is not the only requirement for maintaining a suitable fixed wireless communication connection for millimetre wave fixed wireless links. Rain, snow, and hail can create large changes in the channel gain between transmitter and receiver. For a fixed 605 metre wireless hop operating at 38 GHz over several different days and day timings revealed that on a clear day, the received signal level is-47 dBm, and during a relatively light 40 mm/hr rain rate, the received signal level drops 4.8 dB to – 51.8 dBm. However, when measured during a hail storm, the received signal level drops.

2.11 WIRELESS LOCAL AREA NETWORKS (WLANs)

The Federal Communications Commission (FCC) allocated 300 MHz of unlicensed spectrum in Industrial Scientific and Medical (ISM) band of 5.150-5.350 GHz and 5.725-5.825 GHz for supporting low power licence-free spread spectrum data communication. In 1987, IEEE 802.11 WLAN standard was founded and in 1990 this standard became popular for the use of Internet and Wireless Communication. IEEE 802.11 was restandardized in 1997. In 1999, high rate standard IEEE 802.11 b was approved. The WLAN basically links two

or more devices using some wireless distribution method like spread spectrum or OFDM radio. This gives users the mobility to move around within a local coverage area called a cell.

2.11.1 Types of Wireless LANs

- *Peer to peer:* Peer to peer network allows wireless devices to directly communicate with each other. There is no base station and no one gives permission to talk. It means two devices can communicate to each other within their range without involving the central access point.
- *Bridge:* A bridge can be used to connect networks, typically of different types. A wireless Ethernet bridge allows the connection of device on a wired Ethernet network to a wireless network. The bridge acts as the connection point to the wireless LAN.

2.11.2 Wireless Distribution System

A wireless distribution system is a system that enables the wireless interconnection of access points in an IEEE 802.11 network. It allows a wireless network to be expanded using multiple access points without the need for a wired backbone to link them, as is traditionally required. The main advantage of WDS over other solutions is that it preserves the MAC addresses of client packets across links between access points.

2.11.3 WLAN Protocols

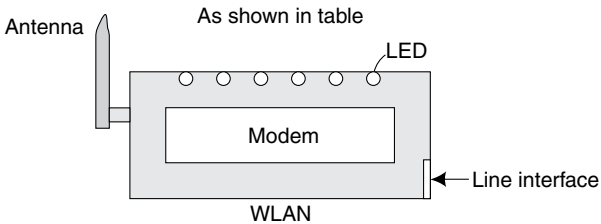


Fig. 2.4

- ***802.11-1997(Legacy):*** The original version of standard IEEE 802.11 was released in 1997 and clarified in 1999. It specified two net bit rates of 1 or 2 Mbits/sec, plus forward error correction code. It specified three alternative physical layer technologies: diffuse infrared operating at 1 Mbit/sec, frequency-hopping spread spectrum operating at 1 Mbit/sec or 2 Mbit/sec and direct sequence spread spectrum operating at 1 Mbit/sec or 2 Mbit/sec. Legacy 802.11 with direct sequence spread spectrum was rapidly supplanted and popularized by 802.11 b.
- ***802.11 a:*** The 802.11 a standard uses the same data link layer protocol and from format as the original standard, but an OFDM based air interface. It operates in the 5 GHz band with a maximum net data rate of 54 Mbits/sec,

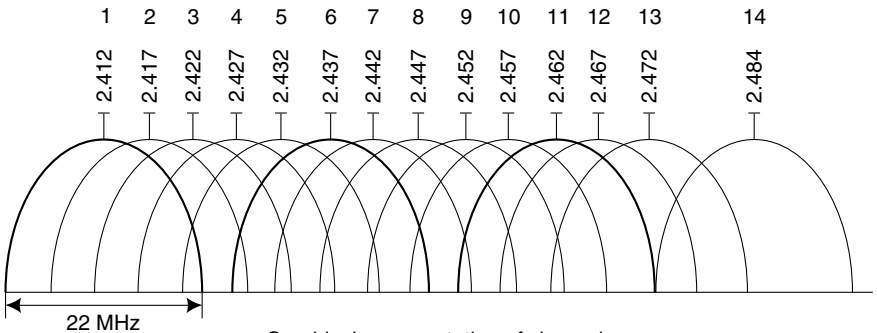
plus error correction code. In theory 802.11 a, signals are absorbed more readily by walls and other solid objects in their path due to their smaller wavelength and as a result cannot penetrate as far as those of 802.11 b.

- ***802.11 b:*** 802.11 b has a higher range at low speeds. It has a maximum raw data rate of 11 Mbits/sec and uses the same media access method defined in the original standard. 802.11 b products appeared in the market in early 2000. The dramatic increase in throughput of 802.11 b along with simultaneous substantial price reductions led to the rapid acceptance of 802.11 b as the basic wireless LAN technology. 802.11 b devices suffer from interference with other products operating at 2.4 GHz band like Bluetooth devices, baby monitors and cordless telephones.
- ***802.11 g:*** This works in 2.4 GHz band like 802.11 b but uses the same OFDM based transmission scheme as 802.11 a. It operates at 54 Mb/sec. Due to its higher speed it became popular. But 802.11 g also suffers from interference as that of 802.11b. Eight amendments came in 802.11 and these are 802.11 a, b, d, e, g, h, i and 802.11 j. These were mixed in 2003 and a new standard was created known as 802.11 ma standard and 2007 it was renamed as the base standard 802.11-2007.
- ***802.11 n:*** 802.11 n is a recent amendment which improves upon the previous 802.11 standard by adding multiple input multiple output (MIMO) antennas. 802.11 n operates on both the 2.4 GHz and the lesser used 5 GHz bands. It was published in October 2009.

2.11.4 Data Transmission in 802.11 Standard (WLAN)

Basically data is transmitted by using different channels now say 2.4 GHz band is available for WLAN. This band is subdivided into a number of channels generally 13-14 channels with greater channel width and overlapping.

Example 2.1 Say the defined band is 2.4000-2.4835 GHz it is divided into 13 channels as shown in figure. Each channel bandwidth is 22 MHz spaced only by 5 MHz.



Graphical representation of channels

Fig. 2.5

- *Address field:* An 802.11 frame can have upto four address fields. Each field can carry a MAC address. Address 1 is the receiver, Address 2 is the transmitter, Address 3 is used for filtering purpose by receiver.
- *Sequence control field:* It is a two-byte section used for identifying message order as well as eliminating duplicate frames. The first 4 bits are fragmentation number and last 12 bits are sequence number.
- *Frame body field:* It is variable in size it can vary from 0 to 2304 bytes plus any overhead from security encapsulation and contains information from higher layers.
- *The frame check sequence:* These are the last four bytes in the standard 802.11 frame. These are referred to as cyclic redundancy check (CRC), it allows for integrity check of retrieved frames. As frames are about to be sent, the FCS is calculated and appended. When a station receives a frame it can calculate the FCS of the frame and compare it to the one received. If they match, it is assumed that the frame was not distorted during transmission.

Management Frames Contain the Following Fields. Some Common Subtypes are as follows

- *Authentication frame:* 802.11 authentication begins with the wireless network interface card (WNIC) by sending an authentication frame to the access point containing its identity.
- *Association request frame:* These are sent from a station it enables the access point to allocate resources and synchronize. The frame carries information about the WNIC including supported data rates and the SSID of the network the station wishes to associate with. If the request is accepted, the access point reserves memory and establishes an association ID for the WNIC.
- *Association response frame:* This is sent from an access point to a station containing the acceptance or rejection to an association request. If it is an acceptance, the frame will contain information such an association ID and supported data rates.
- *Beacon frame:* It is sent periodically from an access point to announce its presence and provide the SSID and other parameters for WNICs within range.
- *Deauthentication frame:* This is sent from a station wishing to terminate connection from another station.
- *Disassociation frame:* This is sent from a station wishing to terminate connection. This is a suitable way to allow the access point to relinquish memory allocation and remove the WNIC from the association table.

- *Probe request frame:* This is sent from the station when it requires information from other station.
- *Probe response frame:* Sent from an access point containing capability information, supported data rates, etc. after receiving probe request frame.
- *Reassociation request frame:* A WNIC sends a reassociation request when it drops from range of the currently associated access point and finds another access point with a stronger signal. The new access point coordinates the forwarding of any information that may still be contained in the buffer of previous access point.
- *Reassociation response frame:* This frame is sent from an access point containing the acceptance or rejection to a WNIC reassociation request frame. The frame includes information required for association such as the association ID and supported data rates.

Control Frames

The control frames control the exchange of data frames between stations. Some control frames are as follows.

- *Acknowledgement (Ack) frame:* The receiving station sends an acknowledgement frame to the sending station after receiving the data without error. If the Ack frame not is received within the predetermined time by the transmitter, then transmitter resends the data frames.
- *Request to send frame (RTS):* The request to send (RTS) and clear to send (CTS) frames provide an optional collision reduction scheme for access point with hidden stations. RTS is sent from the receiver to transmitter for transmitting the information while CTS is sent by transmitting station to the receiving station in response to RTS to show that the data is being sent.

2.12 PAN (PERSONAL AREA NETWORK)

It is the interconnection of information technology devices within the range of an individual person, typically within the range of 10 metres like a person travelling with a laptop, a Personal Digital Assistant (PDA) and a portable printer could interconnect them without having to plug anything in using some form of wireless technology. Typically this kind of Personal Area Network could also be interconnected without wires to the Internet or other networks. The basic difference between PAN and WAN is that PAN is centred around one person while the latter is a local area network that is connected without wires and serves multiple users. The concept of PAN first was developed by Thomas Zimmerman and other researchers at MITs media lab and later supported by IBM's Almaden research

lab. The Personal Area Networks can be constructed with cables or wirelessly USB and firewire technologies often link together a wired PAN while wireless PANs typically use Bluetooth or sometimes infrared connections. Bluetooth PANs are also called piconets.

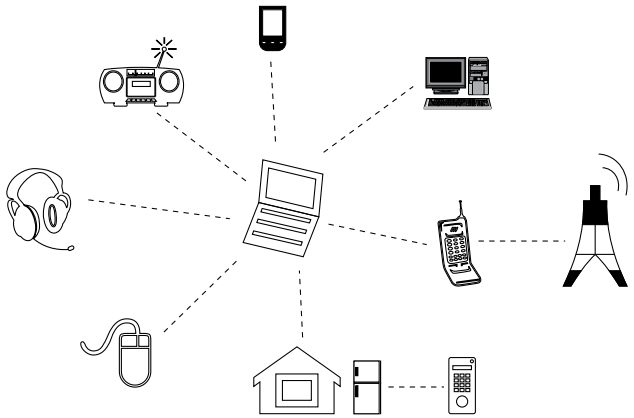


Fig. 2.6

Piconet is formed by the composition of up to 8 active devices in a master-slave relationship. The first Bluetooth device in the piconet is called master and all other devices are called slaves. These slave devices communicate to master device within the range of 10 metres (33 feet). If the slave devices are more than seven, then they can be connected to master device only in special mode called "parked" mode. A Wireless Personel Area Network (WPAN) is a Personal Area Network which connect the devices wirelessly. A WPAN could serve to interconnect all the ordinary computing and communicating devices that many people have on their desk or carry with them. The Bluetooth is the best example of WPAN. It uses the standard IEEE 802.15.

2.13 BLUETOOTH

Bluetooth is a wireless protocol for exchanging data over short distances from fixed and mobile devices, creating personal area networks (PANs). It can connect several devices, overcoming problems of synchronization. Bluetooth uses a radio technology called frequency hopping spread spectrum in its basic mode, the modulation is Gaussian frequency shift keying (GFSK). It can achieve a gross data rate of 1 Mb/s. Bluetooth provides a way to connect and exchange information between devices such as mobile phones, telephones, laptops, personal computers, printers, GPS receivers, digital cameras, and video game consoles through a secure, globally unlicensed industrial, scientific and medical (ISM) 2.4 GHz short range radio frequency bandwidth.

transmitter uses spread-spectrum transmitting automatically, it is unlikely that the 2 transmitters will be on the same frequency at the same time. This technique minimizes the risk that portable phones will disturb Bluetooth devices, since any interference on a particular frequency will last only for a tiny fraction of a second.

When Bluetooth-capable devices come within the range of one another, an electronic conversation takes place to determine whether they have data to share or whether one needs to control the other. The user doesn't have to press a button or give a command—the electronic conversation happens automatically. Then the devices form a network. Bluetooth creates a personal area network (PAN) or piconet, that may fill a room or may encompass no more distance than that between the cellphone on a belt-clip and the headset on your head. Once the piconet is established, the members randomly hop frequencies, so they stay in touch with one another and avoid other piconets that may be operating in the same room.

2.13.6 Bluetooth Security

Bluetooth offers several security modes, and device manufacturers determine which mode to include in a Bluetooth-enabled gadget. In almost all cases, Bluetooth users can establish "trusted devices" that can exchange data without permission. When any other device tries to establish a connection to the users' gadget, the user has to decide to allow it. Service-level security and device-level security work together to protect Bluetooth devices from unauthorized data transmissions. Security methods include authorization and identification procedures that limit the use of Bluetooth services to register user and require that users make a conscious decision to open a file or accept a data transfer. As long as these measures are enabled on the user's phone or other device, unauthorized access is unlikely. An user can also simply switch his Bluetooth mode to non-discoverable and avoid connecting with other Bluetooth devices entirely.

Still, early cellphone virus writers have taken advantage of Bluetooth's automated connection process to send out infected files. However, since most cellphones use a secure Bluetooth connection that requires authorization and authentication before accepting data from an unknown device, the infected file typically doesn't get very far, when the virus arrives in the user's cellphone, the user has to agree to open it and then agree to install it. This has, so far, stopped most cellphone viruses from doing such damage.

2.13.7 Computer Requirements

A personal computer must have a Bluetooth adapter in order to communicate with other Bluetooth devices. While some desktop computers and more recent laptops come with a built-in Bluetooth adapter, others will require an external one in the form of a dongle as shown in Fig. 2.6 (a).

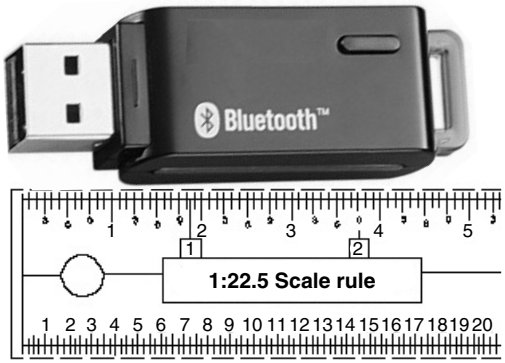


Fig. 2.6(a)

2.13.8 Mobile Phone Requirements

A mobile phone that is Bluetooth enabled is able to pair with many devices to answer the broadest support of feature functionality together with legacy devices-control. The OMTP forum has recently published a recommendation paper that recommends two classes: Basic and Advance.

2.13.9 Bluetooth Versions

There are various versions available, they are Bluetooth 1.0 and 1.0 B which are the earlier versions, the newer versions were developed to counter the problems faced by them.

- **BLUETOOTH 1.1**
  - Ratified as IEEE standard 802.15.1 # 2002
  - Many errors found in 1.0 B specifications were fixed
  - Added support for non-encrypted channel
  - Received signal strength indicator
- **BLUETOOTH 1.2**
  - Faster connection and discovery
  - Adaptive frequency hopping spread spectrum
  - High transmission speeds, upto 721 kb/s
  - Extended synchronous connection which improve voice quality of audio links
  - Host controller interface (HCI) support for 3-wire UART
  - Ratified as IEEE standard 802.15.1-2005
- **BLUETOOTH 2.0**

  It introduced enhanced data rate (EDR) for faster data transfer and uses GFSK and PSK combination for modulation

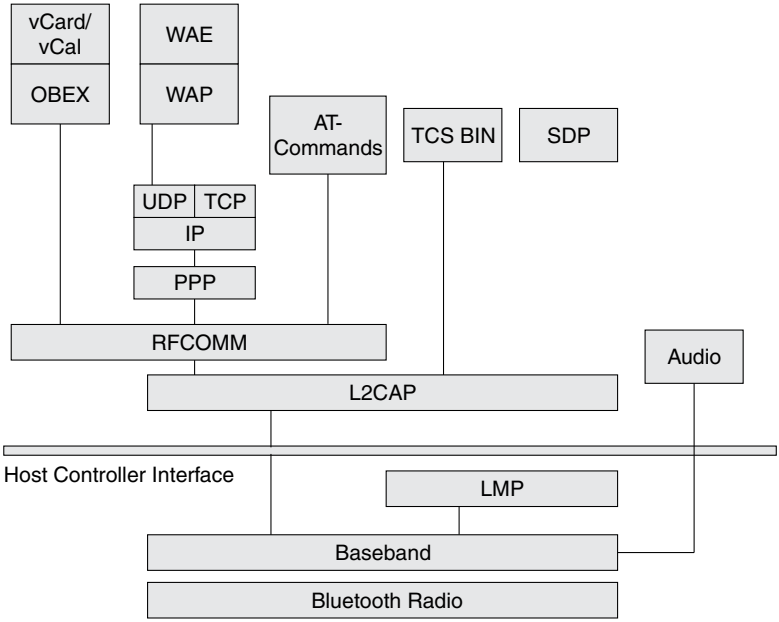


Fig. 2.7

BNEP (Bluetooth Network Encapsulation Protocol)

- Its main purpose is the transmission of IP packets in the personal area networking profile.

AVCTP (Audio/Visual Control Transport Protocol)

- Used by the remote control profile to transfer AV/C commands over an L2CAP channel.

AVDTP (Audio/Visual Data Transport Protocol)

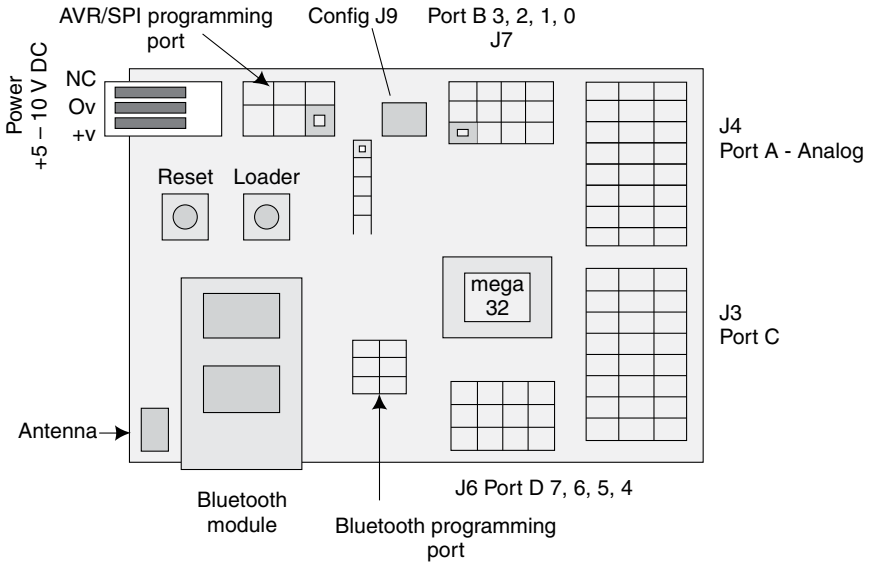
- Used by the advanced audio distribution profile to stream music to stereo headsets over an L2CAP channel.

Telephone Control Protocol

- It defines the call control signalling for the establishment of the voice and data calls between Bluetooth devices

Adopted Protocols

- They include
  - Point-to-point protocol (PPP)
  - TCP/IP/UDP
  - Object Exchange Protocol (OBEX)
  - Wireless application environment/wireless application protocol (WAE/WAP)



1,2 – Program AVR

2,3 – SPI Bus

3,4 – Reset BT

Fig. 2.8

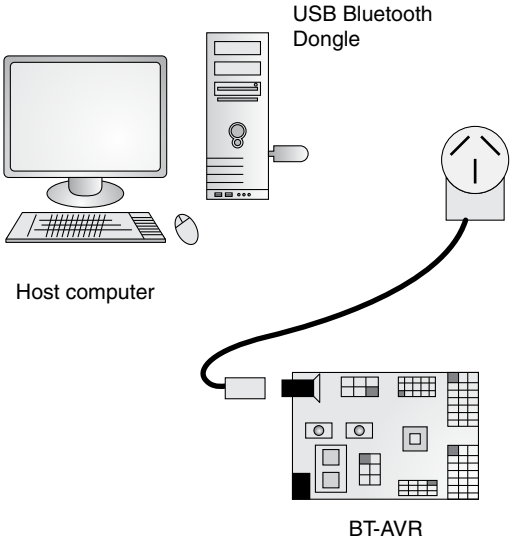


Fig. 2.9